Firm Characteristics and Modes of University-Industry Collaboration: Cases of Japan and Thailand†

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Abstract

Despite the importance of university-industry collaboration, issues pertaining to the characteristics of collaborating firms, their modes of interaction, and the relationship between these modes and outcomes are not well-researched. The impact of country's development on these issues is also unclear. This case study examines Japan and Thailand—respectively representing developed and developing countries—and features the following key findings: 1) the characteristics of firms affect modes, with large Japanese firms being more collaborative with universities, whereas Thai SMEs significantly collaborate more with universities; 2) the relationship between modes in Thai firms is stronger than those of Japanese firms because in Thailand, perhaps due to weak technological capacity, R&D collaboration is conducted alongside university consultancy services; and 3) in Japan, R&D and human resource development collaboration lead to product innovation, whereas different outcomes are expected from different modes in Thailand. Apparently, trivial informal collaborations do have significant impact on innovation.

Keywords
firm characteristics, mode of collaboration, outcome of collaboration, university-industry collaboration

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1. INTRODUCTION

It is widely accepted that knowledge transfer activities between academic and private sectors contribute to firms' competitiveness and the growth of the economy as a whole (Hitt, Ireland, & Lee, 2000). Scholars from several schools of thought—namely innovation systems, Triple Helix, and technology management—make significant attempts to understand the nature and effectiveness of university-industry collaboration (UIC). The most specialized and well-known group of these scholars are in the so-called "Triple Helix" studies. The Triple Helix concept is based on how bilateral relations between government and university, academia and industry, and government and industry have expanded into triadic relationships.

According to the Triple Helix concept, knowledge is created throughout the three main functions of universities: 1) the education of workers; 2) the development and dissemination of research work; and 3) their active participation in social and economic development (Etzkowitz & Leydesdorff, 2000; Van Looy, Callaert, & Debackere, 2006). Knowledge or technology transfer is made through various modes, from patent licensing to consultancy and collaborative R&D (Hermans & Castiaux, 2007), and the selected mode should depend on not only universities as sources of knowledge but the specific nature of the firms themselves, such as the firm's size, industrial sector, and technological capability. Despite the debate surrounding the influence of firms' characteristics, few studies assess the effectiveness of each mode through examining the outcomes of collaboration (Iqbal, Khan, Iqbal, & Senin, 2011; Majid & Ismail, 2009). There are several indicators—such as patents, publication, training—available to operationalize outputs from university and industry alliances. Outcome indicators include product innovation, process innovation, sales, and profit.

This paper sheds light on the above issues through questions such as: do the characteristics of firms affect modes of collaboration? Do the modes relate to each other? And how do they affect outcomes?

2. LITERATURE REVIEW

There are many approaches to examining university-industry collaboration, including national innovation systems, Triple Helix, and technology management. Scholars of these approaches agree that universities are an important source of new knowledge for industries (Agrawal, 2001; Danell & Persson, 2003). The collaboration between universities and industries is also considered a major factor contributing to successful innovation and growth in the past two decades (Iqbal, Khan, & Senin, 2012; Leydesdorff & Fritsch, 2006; Majid & Ismail, 2009). Other historical evidence is the fact that many of the most prestigious universities in the United States, such as the Massachusetts Institute of Technology, were established in large part to support research between academia and industry (Etzkowitz, 1998; Santoro, 2000).

Triple Helix was originated by Jorge Sábato in the 1960s through a concept called Sabato's Triangle (Mello, 2011). This initial concept stipulated that the government should have an active role in stimulating and facilitating the creation of innovation (Mello, 2011). In contrast, the Triple Helix model posits multiple sources of initiative arising from each sphere individually and in collaboration with one or two others (Ranga & Etzkowitz, 2013). As mentioned earlier, the relationship among these three spheres (government, academia, and industry), while emerging from different institutional starting points, have the common purpose of stimulating knowledge-based economic development. With an increased awareness for and the transition into a knowledge-based economy consisting of largely science-based industries, the importance of university-industry collaborations has also come to the fore, with the university primarily regarded as a source of human resources, knowledge and technology (Etzkowitz, 1998).

Nonetheless, the flow of collaboration does not only depend on universities in their role as sources of knowledge and technology (Etzkowitz, 1998) or on the government as a stimulator and facilitator for creating innovation (Mello, 2011); the firms' characteristics also affect collaboration. As to characteristics, this paper focuses on only firm size and industrial sector due to data limitations. Existing literature indicates the importance of firm size (Arundel & Geuna, 2004; Cohen, Nelson, & Walsh, 2002; Mohnen & Hoareau, 2003; Laursen & Salter, 2003), where larger firms tend to collaborate more than small firms because a certain amount of resources is required for participating in R&D activities. However, this very issue is debated due to the emergence of small high-tech firms in the United States and Taiwan (Best, 2001). Motohashi (2004) also points out a new trend of university-industry collaboration, where small and young firms due to insufficient R&D resources collaborate more extensively with universities. Owing to these contradicting arguments, the relationship between firm size and the degree of collaboration with universities remains ambiguous.

On the impact of the industrial sector, Freeman (1995) concludes that industrial specificity is important in explaining variances in the intensity, nature, and drivers of innovation activity. Likewise, Rasiah and VGR (2009) mention that the intensity of industry-university R&D collaboration varies by industry. Schartinger, Rammer, Fischer and Frohlich (2002) identified that high-technology sectors have a high level of interaction whereas low-technology sectors have weak interaction.

The modes of this collaboration include, but are not limited to: conferences, publications/reports, student theses, technical assistance, consultancy, personnel exchange, patents, licenses, joint R&D projects, contract R&D, science and technology parks, equipment and facilities, and spin-offs. Interaction can take place between individual researchers at both universities and companies or between a company and a university (Agrawal & Henderson, 2002; Bekkers & Freitas, 2008; Eun, 2009; Iqbal, et al., 2011; Joseph & Abraham, 2009, Landry, Amara, & Ouimet, 2005; Meyer-Krahmer & Schmoch, 1998; Rast, Khabiri, & Senin, 2012). Interestingly, several studies describe the simultaneous use of various modes. Meyer-Krahmer and Schmoch (1998) report the results of a survey among German academics on the importance of various types of links with industry, finding that collaborative research and informal contacts were highly valued. Similarly, D'Este and Patel (2007) conclude that researchers (in sciences and engineering) in the UK used a wide variety of such channels, such as consultancy and contract research, joint research, training, meetings and conferences, and the creation of new physical facilities (e.g., spin-offs). Regarding this issue, it would be interesting to investigate whether the simultaneous use of various modes affects the collaboration outcomes. Despite thorough attempts by innovation scholars (Agrawal & Henderson, 2002; Cohen, et al., 2002; Cohen, Florida, Randazzese, & Walsh, 1998; Shane, 2002) to analyze the importance of modes through which knowledge flows from public research institutes (PRIs) and universities into industries, there is little consensus regarding the most effective mode of collaboration as evaluated by outcomes (Bekkers & Freitas, 2008; Eun, 2009). Theoretical gaps exist concerning two main issues—namely, the influence of the characteristics of firms and of collaboration modes.

3. RESEARCH QUESTION, FRAMEWORK, AND METHDOLOGY

3.1. Research Question

The theoretical gaps identified in the literature review section point to the following research questions:

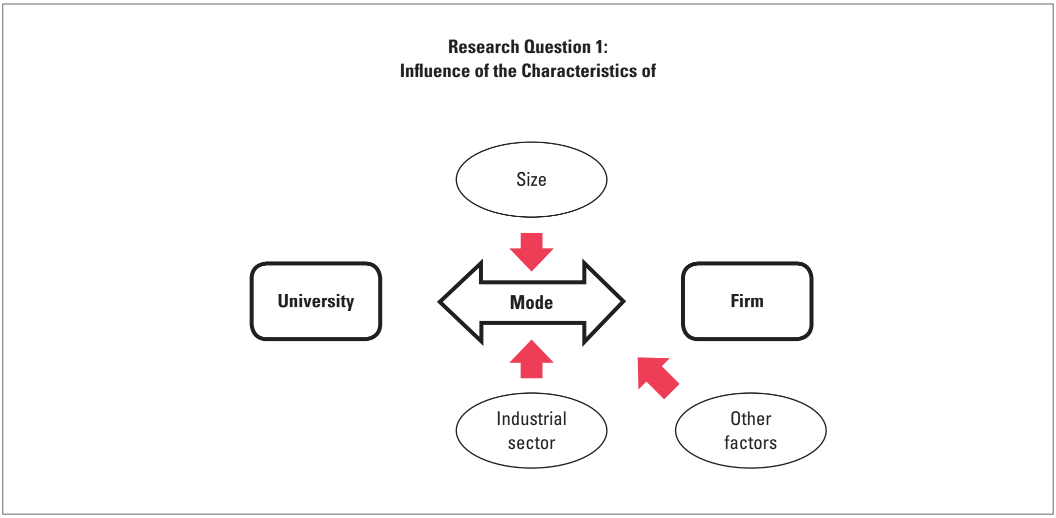
1) Research question 1: regarding the influence of the characteristics of firms
    1.1) Do the characteristics of firms affect modes of collaboration?
2) Research question 2: regarding the influence of modes
    2.1) Do the modes of collaboration affect outcomes?
    2.2) Do the modes relate to each other? And how do these relationships between modes affect outcomes?

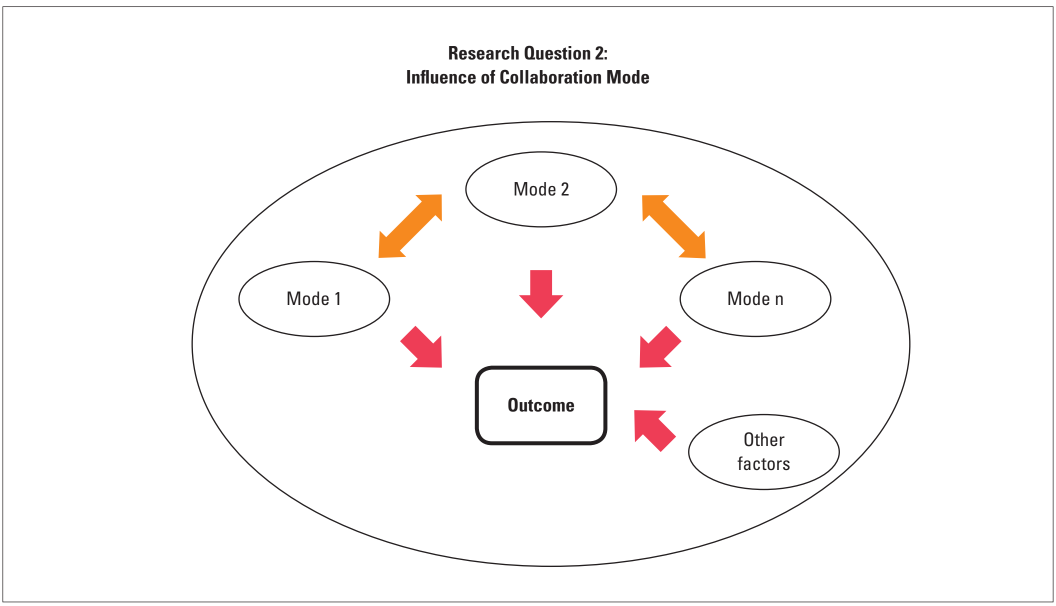
Japan and Thailand are selected as case studies for their particular relationship. Japan is the top foreign investor in Thailand, with Japan's Foreign Direct Investment (FDI) into Thailand accounting for 60.6% of Thailand's national total. Previous studies conclude that FDI is important for disseminating advanced knowledge into both local firms and universities. For example, Kramer, Diez, Marinelli, and Iammarino (2009) conducted forty in-depth interviews of senior managerial and technical staffs of multinational enterprises (MNEs) in both Germany and the UK, and find that MNEs contribute to regional human capital by participating in local skills transfer programs and by engaging in educational partnerships with universities. For their part, "MNEs benefit from inter-firm mobility in highly innovative regions and from the spatial and relational proximity to local universities from which they can access both graduates and more senior personnel as well as know-how (e.g., through contract research) (Kramer, et al., 2009, p. 40)."

3.2. Research Framework

Based on the research framework in Figure 1, three groups of variables are investigated; a) the characteristics of firms, b) the mode of university-industry collaboration and c) the outcome of university-industry collaboration.

FIGURE 1. Research Framework





3.3. Research Methodology

3.3.1. Data Sources

1) Japan

Japanese data come from a survey jointly conducted by the National Graduate Institute for Policy Studies (GRIPS), the Office of Economic and Industrial Research in the National Diet's House of Representatives, and the research company Teikoku Databank (TDB). Questions concerning university-industry collaboration were attached to a regular Teikoku Databank survey titled "TDB Survey of Business Trends." The target group is firms in all types of industries in Japan. The questionnaires were sent to 20,455 firms through e-mail. Returned questionnaires number 10,731 or a 52.5% response rate (Table 1). Respondents were asked to include some basic information such as their prefecture, number of employees, capital, and industry (Saito & Sumikura, 2010). However, only firms conducting or formerly conducting R&D activities (2,644 firms) were asked to answer questions about collaboration with universities.[1] Therefore, this paper includes only these firms (2,644 firms) as the target group for data analysis.

TABLE 1. Summary of General Information on the GRIPS Firm Survey

Items	Japan
Survey name	GRIPS Firm Survey (occasional survey)
Data availability by year	2009
Nature of survey	Voluntary
Survey method	Sampling • Firms which followed up a white paper on business climate per year were requested to fill in the questionnaires through e-mail.
Coverage	51 industries
Response rate (for year covered)	10,731 firms (52.5%)

Source: Saito and Sumikura (2010)

2) Thailand

Thailand's R&D and Innovation Survey has been commissioned by their Ministry of Science and Technology since 1999[2] towards gaining a better understanding of the nature of R&D and innovation activities in Thailand's industry, and to find ways of support. The results from the latest survey in 2011 indicate that 744 firms (out of 4,246 returned questionnaires) engage in R&D and innovation

[1] The questions in the questionnaire concern: 1) whether the firm conducts, used to conduct, or does not conduct R&D activities; 2) their research results developed through collaboration classified by field; 3) the utilization of their research results; 4) their modes of collaboration; 5) the impact of collaboration on product innovation; 6) difficulties in generating product innovation; and 7) the impact of collaboration on sales. The survey did not ask the respondents to specify amounts of R&D spending.

[2] Years 2002 to 2006 carried out by the National Science and Technology Development Agency. Years 2008 to present carried out by the National Science Technology and Innovation Policy Office.

activities. Both R&D and non-R&D firms answered questions about collaboration with universities. Nonetheless, in order to compare with Japanese data, the target group for data analysis is limited to collaborating firms conducting or formerly conducting R&D activities (452 firms; Table 2).

TABLE 2. Summary of General Information on the R&D and Innovation Survey

Items	Thailand
Survey name	National Survey of R&D and Innovation 2011 (regular survey)[3]
Data availability by year	2011
Nature of survey	Voluntary
Survey method	1. SET100 (top 100 listed companies in the Thai stock exchange) 2. Repetitive group (Panel)[4] 3. Non-repetitive group (stratified sampling and systematic random sampling)[5]
Coverage	25 industries in the manufacturing sector, 17 industries in the service sector and 5 industries in the wholesale/retail sector
Guidelines	Frascati Manual and Oslo Manual
Response rate (for year covered)	4,246 firms (43.5%)

Source: National Science Technology and Innovation Policy Office (2014)

3.3.2. Variable Measurement

This paper employs a quantitative research approach. The variables for all research questions are summarized in Table 3.

To examine the first research question, two independent variables were selected for investigation: the number of employees (size) and selected industrial sectors (food, chemical, electrical apparatus, and automotive). In term of dependent variables, single modes were included in the equations: twelve modes in the Thai case were classified into six groups, while in the Japanese case, eight modes were classified into five groups (see Appendix Table B). Probit regression was applied to analyze the influence of the characteristics of firms (independent variables) on different modes of collaboration (dependent variables).

Concerning the second research question, regarding the influence of collaboration modes on collaboration outcomes, the characteristics of firms such as size and industrial sector (manufacturing sector) were included as control variables.

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[3] The issue of university-industry collaboration was occasionally included in the National Survey of R&D and Innovation.

[4] The National Science and Technology Development Agency (NSTDA), National Innovation Agency (NIA), National Research Council of Thailand (NRCT), and the Thailand Research Fund (TRF).

[5] Two techniques (stratified and systematic random sampling) were applied to this survey. All firms in this set were divided into three groups: 1) firms with highest revenue (1% of total firms; all firms are samples); 2) excluding group 1, firms with highest revenue (10% of total firms; all firms are samples); and 3) the remainders (systematic random sampling technique based on revenue).

Collaboration mode (independent variable): Both single modes and complementary modes were included in the equations. To obtain complementary modes, we investigated the relationships between modes by calculating correlation coefficients, after which three pairs of the strongest correlation coefficients were multiplied and included as independent variables.

Collaboration outcome (dependent variable): In Japan's case, the dependent variables were grouped into four levels by percentage of product innovation developed through collaboration and percentage of the contribution of outcomes developed through collaboration to sales.[6] Ordered probit regression was used to measure outcomes of dependent variables at ordinal scale. In the Thai case, poisson regression and linear regression were used to analyze counting number-dependent variables. Unlike Japan, all outcomes (product innovation, process innovation and amount of total sales) are continuous numbers.[7]

TABLE 3. Variable Names

Variable name	Proxy variables	
	Japan	Thailand
number of employee (size)[8]	>200 employees (1), ≤200 employees (0)	
manufacturing	manufacturing (1), non-manufacturing (0)	
food[9]	food (1), non-food (0)	
chemical[10]	chemical (1), non-chemical (0)	
electrical apparatus[10]	electrical apparatus (1), non-electrical apparatus	
automotive[10]	automotive (1), non-automotive (0)	
single mode	1. R&D mode level 1: use one of all sub-modes, level 4: use all sub-modes	1. R&D mode level 1: use one of all sub-modes, level 3: use all sub-modes
	1. Technical guidance mode use technical guidance (1), otherwise (0)	2. Consultancy mode use consultancy service (1), otherwise (0)
	3. Personnel exchange mode host personnel exchange (1), otherwise (0)	3. HR mode level 1: use one of all sub-modes, level 3: use all sub-modes
	4. Technology licensing mode license technology (1), otherwise (0)	4. Technology licensing mode license technology (1), otherwise (0)

6 The questionnaire did not identify a time span for innovation outcomes. This survey was conducted in 2009.

7 The time span for innovation outcome is one year (2011).

8 Based on classifications from the Office of Small and Medium Enterprises Promotion, Thailand (small and medium: ≤200 employees, large: > 200 employees). The authors used Thai criteria (≤ 200 employees as SMEs) because not all data (actual value) was allowed for the authors to use. It is possible that Japanese firms with 201-300 employees (174 firms out of 2,644 firms) received government support for SMEs and government policy may affect the results. Nonetheless, government policy cannot be included in the equations because this data was not included in the Japanese survey.

9 The following four industrial sectors were selected according to frequency of collaboration (based on Thai data) and the comparability between Japanese industrial classification and Thai industrial classification: (a) food, (b) chemical (c) electrical apparatus and (d) automotive.

10 See Appendix Table B

Variable name	Proxy variables	
	Japan	Thailand
	5. Venture business mode establish business venture mode (1), otherwise (0)	5. Infrastructure mode level 1: use one of all sub-modes, level 2: use all sub-modes
		6. Informal mode level 1: use one of all sub-modes, level 2: use all sub-modes
complementary mode	1. R&D * Technology licensing 2. R&D * Personnel exchange 3. Consultancy * Personnel exchange	1. R&D * Consultancy 2. Consultancy * Technology licensing 3. R&D * Technology licensing
outcome of collaboration	1. Product innovation developed through collaboration (% of total products) (level 1-4) level 1: 0% < x < 10%, level 2: 10% < x < 30%, level 3: 30% < x < 100%, level 4: 100% 2. Contribution of outcomes developed through collaboration to sales (level 1-4) level 1: 0% < x < 10%, level 2: 10% < x < 30%, level 3: 30% < x < 100%, level 4: 100%	1. Number of product innovations developed through collaboration • Counting number 2. Number of process innovations developed through collaboration • Counting number 3. Amount of total sales • ln (amount of total sales)

4. OVERVIEW OF UNIVERSITY-INDUSTRY COLLABORATION POLICY

4.1. Japan

Japanese policies for promoting university-industry collaboration began in the 1980s, but the majority of initiatives have been carried out since the 1990s. Japanese government policy focuses on promoting specific modes of collaboration; for example, the government promoted cooperative R&D activities through setting up a contract research and joint research system in the 1980s. Later on, intellectual property rights issues were promoted due to the influence of US government policy. Legislation for promoting the establishment of technology licensing offices (TLO) at universities was enacted in 1998, followed by the Japanese Bayh-Dole Act. The Japanese Bayh-Dole Act enables an ownership transfer of intellectual property rights to universities. However, national universities at the time were subordinate to the government and could not own intellectual property rights. The enactment of the National University Corporation Law made national universities autonomous, allowing them to own intellectual property rights. In 2000-2001, the Japanese government encouraged universities to set up business ventures through the Industrial Technology Enhancement Act and the Hiranuma Plan (1,000 university-originated ventures in three years). In 2002, university-originated ventures were authorized to use national universities' technical facilities (MEXT, 2014). Recently, the Japanese government enacted the Industrial Competitiveness Enhancement Act allowing national universities to set up venture funds to invest in spin-off firms (Kagami, 2013).

At the regional level, local governments and research institutes also actively assist industry. Japan's local public industrial technology research institutes, or "Kosetsushi Centers," were established in 1902 and are operated by prefectural or local governments under the guidance of the Ministry of Economy, Trade, and Industry (METI). Kosetsushi Centers hire more than 6,000 staff in 262 offices (or 182 Kosetsushi Centers) in assisting local SMEs (Stephen & Robert, 2011).

4.2. Thailand

Thai Policies regarding university-industry collaboration began in the 1990s. Thailand's Ministry of Science and Technology (MOST) and Ministry of Education (MOE) are the key actors behind these policies. MOST's National Science and Technology Development Agency (NSTDA) set up the Industrial Technology Assistance Program (ITAP) in 1992, aiming to strengthen the innovative competitiveness of Thai SMEs and to create networks with experts in universities. In doing so, the program provides technology transfer through both R&D and consultancy modes to Thai companies engaging in R&D and engineering activities (NASTA, n. d.). In 2002, NSTDA opened Thailand's first science park. From 2004 to 2007, science parks were set up in three regions outside of Bangkok. Because there are no local research institutes, Thailand's central government commissioned major universities located in each region to host and operate the aforementioned initiatives; consequently, science parks located in the north are operated by Chiang Mai University, the northeast by Konkaen University, and the south by Prince of Songkla University. They aim at transferring knowledge or technology and providing technical assistance to local businesses, including incubating technology startups. In 2014, MOST began a talent mobility program encouraging university researchers to work with industry as full-time or part-time staff. Researchers who have scholarship bonds with the government can join this program, and work experience within industry functions as compensation for scholarships.

MOE's UIC program initiated the Cooperative Education Program in 2002 (Ruksasuk, 2011). This program normally requires undergraduates to intern within their target industry for at least one semester. In 2004, in order to stimulate technology transfer to industry and provide intellectual property services for university researchers, the Office of Higher Education Commission began encouraging universities to set up technology licensing offices (TLOs) and university business incubators (UBIs; Office of Higher Education Commission, no date). In 1992, the Thailand Research Fund (TRF) was established under the Office of the Prime Minister to provide R&D grants and allocate scholarships for students and researchers that included funding for utilizing research results. Some R&D schemes such as Research and Researchers for Industry (RRI) focus on collaboration with universities and industry (TRF, n. d.).

5. RESULTS AND DISCUSSION

5.1. Influences of the Characteristics of Firms

From ordered probit and probit regression analysis, there was a significant relationship between firm size and R&D collaboration. Nevertheless, results between Thai and Japanese cases were contradictory (Tables 4 and 5). In Japan, larger firms tended to do R&D projects with universities. In contrast, smaller firms in Thailand significantly engaged in R&D collaboration with universities. These contradicting results pose certain implications for the debate on the influence of firm size. Firm size, which impacts R&D resources, is only one factor influencing collaboration with universities. Central and/or local governments could also guide the direction of the collaboration between two parties. In the regional innovation system of Japan, local research institutes actively support local SMEs; as mentioned earlier, the Kosetsushi Centers partially take on the role of local universities in their support of Japanese SME manufacturers. For example, the Kosetsushi Center in Shiga Prefecture provided 6,048 cases of technical consultations and 6,157 instances of equipment service including 24 collaborative R&D projects (Seki, 2008). In addition, larger firms often collaborate with regional Japanese universities as seen from the results of the NISTEP survey on Fukui Prefecture's university-industry collaboration (Nozawa & Yoshinaga, 2013). In Thailand's case, because of the highly significant presence of SMEs in the country (99% of total firms in Thailand, 70% of total employment and 37% of GDP[11]), government policies are geared towards upgrading the technological capabilities of Thai SMEs, such as the ITAP program operated by NSTDA, which closely works with SMEs to support technology transfer through network of knowledgeable and experienced staff in universities. Regional science parks also provide technical assistance for SME R&D projects in local areas.

There were no differences in collaboration between firms and universities across industries in Japan. The collaboration between university and industry in Japan was based on R&D and HR (personnel exchange) modes (Table 4). Notably, Japanese universities offer visiting professorships attached to R&D projects. For example, together with an R&D-sponsored fund, the Tokyo Institute of Technology (TIT) accepts company researchers as specially appointed faculty members, enabling companies to send out visiting researchers in tandem with collaborative R&D projects (TIT, n. d.).

In the Thai case, the R&D intensity of an industry did not matter. Firms probably carry out in-house research. The results are likely to not align with the previous conclusions of innovation studies scholars stating that the industrial sector is another important variable explaining the intensity and nature of innovation activity (Freeman, 1995; Nelson, 2008), and the intensity of industry-university R&D collaboration varies by industry because of different levels of technological capabilities

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[11] Bank of Thailand

(Rasiah & VGR, 2009; Schartinger, et al., 2002). According to the R&D and Innovation Survey of Thailand, the chemical and petroleum industry had the highest amount of R&D spending in 2011. However, results in Table 5 indicate that there was no significant relationship between this sector and the R&D mode. Instead of R&D collaboration, this industry tends to use the technical infrastructure provided by universities and personal connections with university researchers. Interestingly, the food industry was the second largest investor in R&D. Nonetheless, like the petroleum and chemical industry, the food industry has no significant relationship with universities in any modes. In contrast, the automotive industry (moderately investing in R&D) seemed to collaborate with universities through various modes, namely R&D, infrastructure and informal modes. Notably, industries significantly engaging with universities in the informal mode also had collaborations in other modes. This signifies a critical relationship between informal and formal activities.

TABLE 4. Influence of the Characteristics of Firms on Collaboration with Universities: the Japanese Case

Independent variable (characteristics of firm)	Dependent variable (modes of collaboration)							
	R&D mode (level 1-4)				Consultancy mode (binary)	Personnel exchange mode (binary)	Technology licensing (binary)	Venture (binary)
	Level 1	Level 2	Level 3	Level 4				
Food	0.006 (0.005)	0.058*** (0.016)	0.035*** (0.012)	0.012** (0.005)	0.002 (0.020)	0.007 (0.021)	-0.009 (0.017)	-0.024 (0.012)
Chemical	-0.002 (0.008)	0.081*** (0.014)	0.053*** (0.012)	0.018*** (0.005)	0.008 (0.018)	0.028 (0.020)	0.026 (0.019)	-0.014 (0.013)
Electrical apparatus	0.004 (0.006)	0.067*** (0.015)	0.042*** (0.011)	0.014*** (0.005)	0.005 (0.019)	0.053*** (0.024)	0.026 (0.021)	0.023 (0.019)
Automotive	-0.022 (0.027)	-0.033 (0.029)	-0.015 (0.012)	-0.004 (0.003)	-0.004 (0.038)	-0.035 (0.024)	-0.023 (0.028)	0.007 (0.035)
Size	0.012*** (0.002)	0.047*** (0.009)	0.026*** (0.006)	0.008*** (0.002)	0.001 (0.011)	0.053*** (0.014)	0.005 (0.011)	0.010 (0.010)
No. of observations	2,644				2,644	2,644	2,644	2,644
Log likelihood	-3,149.83				-589.89	-599.87	-530.32	-466.50
LR chi2	90.66				0.29	29.76	5.53	6.82
Prob>chi2	0.000				0.9978	0.000	0.355	0.235

*Remark: ***1% level of significance, **5% level of significance, *10% level of significance*

TABLE 5. Influence of the Characteristics of Firms on Collaboration with Universities: the Thai Case

Independent variable (characteristics of firm)	Dependent variable (modes of collaboration)							
	R&D mode (level 1-3)			Consultancy (binary)	Infrastructure mode (level 1-2)		Informal mode (level 1-2)	
	Level 1	Level 2	Level 3		Level 1	Level 2	Level 1	Level 2
Food	0.002 (0.018)	0.003 (0.020)	0.002 (0.014)	0.021 (0.172)	0.137 (0.013)	0.041 (0.042)	0.006 (0.008)	0.030 (0.046)
Petroleum & Chemical	0.007 (0.019)	0.008 (0.023)	0.006 (0.016)	0.239 (0.183)	0.026** (0.012)	0.090** (0.050)	0.013* (0.007)	0.074 (0.054)
Electrical apparatus	-0.065 (0.069)	-0.058 (0.048)	0.031 (0.021)	0.193 (0.476)	-0.010 (0.047)	-0.025 (0.109)	-0.105 (0.064)	-0.213*** (0.067)

Independent variable (characteristics of firm)	Dependent variable (modes of collaboration)							
	R&D mode (level 1-3)			Consultancy (binary)	Infrastructure mode (level 1-2)		Informal mode (level 1-2)	
	Level 1	Level 2	Level 3		Level 1	Level 2	Level 1	Level 2
Automotive	0.051*** (0.014)	0.085** (0.041)	0.080 (0.052)	0.099 (0.331)	0.033*** (0.008)	0.180** (0.099)	0.013* (0.007)	0.172* (0.103)
Size	-0.033** (0.015)	-0.038** (0.018)	-0.027** (0.013)	-0.070 (0.141)	0.005 (0.0122)	0.145 (0.033)	0.001 (0.008)	0.003 (0.038)
No. of observations	452			452	452		452	
Log likelihood	-435.59			214.41	-419.06		-452.08	
LR chi2	10.21			2.25	7.41		9.12	
Prob>chi2	0.069			0.813	0.192		0.104	

*Remark: ***1% level of significance, **5% level of significance, *10% level of significance*

TABLE 5. Influence of the Characteristics of Firms on Collaboration with Universities: the Thai Case (Continue)

Independent variable (characteristics of firm)	Dependent variable (modes of collaboration)			
	HR mode (level 1-3)			Technology licensing (binary)
	Level 1	Level 2	Level 3	
Food	-0.018 (0.018)	0.039 (0.035)	0.011 (0.010)	0.038 (0.037)
Petroleum & Chemical	0.011 (0.011)	-0.033 (0.038)	-0.008 (0.009)	-0.009 (0.037)
Electrical apparatus	-0.020 (0.063)	0.040 (0.103)	0.011 (0.033)	omitted
Automotive	-0.041 (0.051)	0.071 (0.068)	0.022 (0.026)	0.071 (0.085)
Size	-0.012 (0.011)	0.031 (0.029)	0.008 (0.007)	-0.023 (0.029)
No. of observations	452			443
Log likelihood	-473.69			-135.29
LR chi2	5.64			2.67
Prob>chi2	0.342			0.615

*Remark: ***1% level of significance, **5% level of significance, *10% level of significance*

5.2. Influence of Modes on Collaboration

To address certain gaps in previous studies, this study investigates the relationship between modes and outcomes, and also includes two modes in combination (complementary modes) as independent variables in order to compare the effectiveness between single modes and complementary modes.

The relationship between modes in the Japanese case was not strong. The maximum correlation coefficient was approximately 0.15. All modes affected both product innovation and sales, but the most effective modes for generating product innovation and contributing to sales were the technology licensing mode and the personnel exchange mode. Combinations of different modes did not help firms enhance the outcomes of collaboration. Instead of complementation, the results presented substitutions of modes (Tables 6 and 7).

TABLE 6. Relationships Between Modes: the Japanese Case

	R&D mode	Consultancy mode	Personnel exchange mode	Technology licensing	Venture
R&D mode	1.0000				
Consultancy mode	0.0585	1.0000			
HR mode	**0.1467**	**0.1294**	1.0000		
Technology licensing	**0.1539**	0.1250	0.0971	1.0000	
Venture	0.0399	0.0421	0.0766	0.0438	1.0000

TABLE 7. Relationships Between Modes and Outcomes: the Japanese Case

Independent variable	Dependent variable							
	Product innovation				Sales			
	Level 1	Level 2	Level 3	Level 4	Level 1	Level 2	Level 3	Level 4
R&D mode	0.102*** (0.009)	0.054*** (0.004)	0.032*** (0.003)	0.007*** (0.002)	0.170*** (0.011)	0.033*** (0.003)	0.010*** (0.002)	0.001** (0.007)
Consultancy mode	0.027*** (0.009)	0.059*** (0.013)	0.042*** (0.012)	0.012*** (0.005)	0.092*** (0.009)	0.066*** (0.014)	0.028*** (0.008)	0.006* (0.003)
HR mode	-9.022 (0.031)	0.103*** (0.018)	0.087*** (0.022)	0.031*** (0.012)	0.069*** (0.025)	0.101*** (0.023)	0.049*** (0.016)	0.012* (0.007)
Technology licensing	-0.085* (0.046)	0.129*** (0.018)	0.125*** (0.028)	0.053*** (0.019)	0.077*** (0.021)	0.088*** (0.023)	0.041*** (0.015)	0.010* (0.006)
Venture	0.029*** (0.007)	0.051*** (0.014)	0.036*** (0.012)	0.010** (0.004)	0.088*** (0.009)	0.040*** (0.012)	0.015*** (0.006)	0.003 (0.002)
R&D * Technology licensing	-0.074*** (0.015)	-0.040*** (0.008)	-0.023*** (0.005)	-0.005*** (0.001)	-0.106*** (0.024)	-0.021*** (0.005)	-0.006*** (0.002)	-0.001* (0.000)
R&D * Personnel exchange	-0.079*** (0.014)	-0.042*** (0.007)	-0.025*** (0.005)	-0.005*** (0.001)	-0.138*** (0.023)	-0.027*** (0.005)	-0.008*** (0.002)	-0.001* (0.001)
Consultancy * Personnel exchange	0.003 (0.041)	0.002 (0.023)	0.001 (0.014)	0.000 (0.003)	-0.132 (0.105)	-0.015** (0.007)	-0.004** (0.002)	-0.004* (0.000)
Size	-0.019* (0.011)	-0.009* (0.005)	-0.005** (0.003)	-0.001* (0.001)	-0.018 (0.016)	-0.003 (0.003)	-0.001 (0.000)	-0.000 (0.000)
Manufacturing	0.012 (0.008)	0.006 (0.004)	0.004 (0.002)	0.001 (0.001)	0.029** (0.013)	0.006** (0.003)	0.002** (0.001)	0.0002 (0.000)
No. of observations	2,643				2,643			
Log likelihood	-2,323.39				-1,883.68			
LR chi2	570.35				584.44			
Prob>chi2	0.000				0.000			

*Remark: ***1% level of significance, **5% level of significance, *10% level of significance*

In contrast, our Thai results can be generalized as follows:

(A) The relationship between modes is relatively strong (with maximum correlation coefficient of 0.6).

(B) Different modes significantly generate different outcomes.

(C) Complementary modes significantly influence outcomes of collaboration

(D) The HR mode is not effective.

In detail, single modes (infrastructure mode and technology licensing mode) and complementary modes (interaction term of R&D and consultancy mode) significantly affected product innovation. Regarding process innovation, single modes (consultancy mode and R&D mode) were the most effective whereas complementary modes do not enhance process innovation. In term of sales, only complementary modes (R&D and consultancy in combination) had significant relationships whereas single modes do not. Interestingly, the informal mode seems to be trivial, but could have a significant relationship to process innovation (Tables 8 and 9).

The differences between the Japanese and Thai results may be caused by the level of the technological capabilities of the participating firms. Japanese firms are relatively innovative and invest in R&D, whereas only a few large subsidiaries of TNCs, large domestic firms, and SMEs in Thailand have capability in R&D (Intarakumnerd & Lecler, 2010; Odagiri & Goto, 1993). Hence, in the Thai case, R&D and consultancy must be used in combination to enhance outcomes. When a combination of R&D and consultancy were used, it significantly influenced product innovation (1.353 at 5% level of significance) and sales (1.284 at 1% level of significance). This is because firms and universities may not be able to equally contribute to R&D projects. The experts from universities must provide technical consultancy to firms as a guideline for carrying out R&D projects. The personnel exchange mode is effective in Japan since researcher exchange is a part of R&D collaboration projects, but HR mode in Thailand is mostly based on education and not research due to government policy on cooperative education (359 out of 452 surveyed firms host student internship programs). Surprisingly, the infrastructure mode generates substantial outcomes. This implies that most Thai firms do not invest in their own R&D facilities, and therefore universities' laboratories are necessary for these firms to conduct innovation. In addition, the universities' testing services can certify firms' products in accordance with domestic or international standards necessary for exporting to overseas markets. For example, a DNA technology laboratory (DNATEC), jointly established by Kasertsart University and NSTDA, certifies DNA fingerprinting for plants and animals, verifying hybrid or parent seeds and animals' species. The laboratory also certifies to high-quality Thai Jasmine rice for export.

TABLE 8. Relationships Between Modes: the Thai Case

	R&D mode	Consultancy mode	Infrastructure mode	HR mode	Informal mode	Technology licensing
R&D mode	1.0000					
Consultancy mode	**0.5991**	1.0000				
Infrastructure mode	0.4550	0.4538	1.0000			
HR mode	0.3392	0.2787	0.2885	1.0000		
Informal mode	0.4677	0.4095	0.4741	0.3212	1.0000	
Technology licensing	**0.5078**	**0.5068**	0.3709	0.2656	0.2928	1.0000

TABLE 9. Relationships Between Modes and Outcomes: the Thai Case

Independent variable	Dependent variable	
	Product innovation (Poisson regression)	Process innovation (Poisson regression)
R&D mode	0.724 (0.443)	0.716*** (0.269)
Consultancy mode	-3.244 (2.127)	1.806*** (0.451)
Infrastructure mode	4.097*** (2.182)	-1.134*** (0.520)
HR mode	-0.085 (0.266)	-0.467** (0.208)
Informal mode	0.585 (0.369)	0.682*** (0.211)
Technology licensing mode	2.222** (1.192)	-14.396 (957.236)
R&D * Consultancy	1.353** (0.816)	-0.761** (0.312)
Consultancy * Technology licensing	3.088 (2.216)	12.512 (957.236)
R&D * Technology licensing	-2.138*** (0.827)	0.375 (0.561)
Size	-0.506 (0.827)	-0.142 (0.278)
Manufacturing	-0.212 (0.475)	1.595*** (0.599)
No. of observations	452	452
Log likelihood	-84.85	-165.06
LR chi2	99.94	104.83
Prob>chi2	0.000	0.000

*Remark: ***1% level of significance, **5% level of significance, *10% level of significance*

Independent variable	Dependent variable Amount of sales (ln_sales)
R&D mode	0.039 (0.273)
Consultancy mode	-0.956 (0.617)
Infrastructure mode	0.993 (0.668)
HR mode	-0.163 (0.208)
Informal mode	0.211 (0.188)
Technology licensing	1.406 (1.202)
R&D * Consultancy	1.284*** (0.421)
Consultancy * Technology licensing	-1.832 (1.388)
R&D * Technology licensing	-0.972 (0.669)
Size	2.141*** (0.273)
Manufacturing	-0.347 (0.363)
Constant	19.182*** (0.441)
R^2	0.1759
Observations	447

*Remark: 1. ***1% level of significance, **5% level of significance, *10% level of significance*
2. Limitation of data: Size is dummy variable and total sales is continuous number.

6. CONCLUSION

This paper investigates two main issues: 1) the influence of the characteristics of firms on university-industry collaboration, and 2) the influence of modes of collaboration. Thailand and Japan were selected for being representative of developing and developed countries, respectively. Our findings indicated that the characteristics of firms, namely size and industrial sector, influenced collaboration. However, the characteristics of firms were not the only influencing factors; there was a contradiction between Japanese and Thai results. In Japan, *larger firms* carried out R&D activity with universities, whereas in the Thai case, *smaller firms* tended to do so. It is probable that in Japan, local public research institutes support R&D activities in SMEs, as seen in the Industrial Research Center of Shiga Prefecture case (Section 5.1). However, this explanation could not be substantiated by statistical analysis. Further studies on the role of local public research institutes in supporting and upgrading SMEs' capabilities are recommended. In Thailand, there are no local public research institutes; therefore, the government commissions regional universities to host and operate government initiatives. It is not surprising that Thai SMEs had a significant relationship with universities through the R&D mode. The nature of key actors in the Triple Helix concept, especially government policy, does matter.

Modes of collaboration were also important determinants influencing collaboration. In the Japanese case, the technology licensing mode and personnel exchange mode were the most effective modes in generating product innovation and increasing sales. These results provide remarkable implications: 1) promoting technology licensing from universities may be an effective policy for increasing Japanese firms' competitiveness and 2) personnel exchange, as part of collaborative R&D projects, may be an appropriate policy for transferring knowledge or technology to participating firms. In the Thai case, the informal mode, which seems to be trivial, is likely to be an effective mode. Industries using the informal mode also collaborate with universities through other modes. Besides, the informal mode could influence innovation. Therefore, the government should not overlook this mode and could, for example, build concrete networks of researchers across sectors through informal discussion, informal meetings, and conferences. Launching an open laboratory initiative in Thai universities may be suitable. Thai SMEs do not have enough resources to invest in their own R&D facilities. The universities' technical infrastructure can help firms upgrade local products by benchmarking against high-quality products. It can also certify products to match domestic or international standards, allowing them to be exported to overseas markets. In the Thai case, using modes in combination (especially the R&D mode and consultancy mode) help firms enhance outcomes of collaboration; hence, the university should consider offering more comprehensive services to firms.

7. LIMIATION AND FURTHER STUDY

There are some limitations for making cross-country comparisons due to different sources of data. The authors are aware of this issue, and therefore selected only similar questions from both questionnaires as proxies for comparisons. In addition, this paper is based on cross-sectional data analysis because the Japan survey was done only once.

For further study, we suggest analyzing other variables—such as firm age, government policy, or R&D spending—that might be factors affecting collaboration, and conducting regular surveys to collect time series data.

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APPENDIX

TABLE A. Descriptive Statistics

Variable	Observation	Mean	Standard Deviation	Min	Max
1. Japanese Case					
Outcome					
Product innovation	2,644	0.890	0.729	0	4
Sales	2,644	0.775	0.583	0	4
Single mode					
R&D mode	2,644	0.948	0.882	0	4
Technical guidance mode	2,644	0.059	0.235	0	1
Personnel exchange mode	2,644	0.062	0.241	0	1
Technology licensing mode	2,644	0.051	0.220	0	1
Venture mode	2,644	0.043	0.203	0	1
Complementary mode					
R&D * Technology licensing	2,644	0.078	0.439	0	4
R&D * Personnel exchange	2,644	0.090	0.468	0	4
Technical guidance * Personnel exchange	2,644	0.011	0.104	0	1
The characteristics of firms					
Size	2,644	0.208	0.406	0	1
Food	2,644	0.057	0.233	0	1
Chemical	2,644	0.075	0.263	0	1
Electrical apparatus	2,644	0.066	0.249	0	1
Automotive	2,644	0.014	0.117	0	1
2. Thai case					
Outcome					
Product innovation (item)	452	0.073	0.472	0	8
Process innovation (item)	452	0.124	0.752	0	9
Sales (million baht)	447	13,900	122,000	0	2,430,000
Single mode					
R&D mode	452	0.549	0.873	0	3
Consultancy mode	452	0.184	0.388	0	1
HR mode	452	1.166	0.702	0	3
Informal mode	452	0.741	0.859	0	2
Technology licensing mode	452	0.091	0.288	0	1
Infrastructure mode	452	0.591	0.806	0	2

Complementary mode					
R&D * Technology licensing	452	0.177	0.617	0	3
R&D * Consultancy	452	0.303	0.793	0	3
Consultancy * Technology licensing	452	0.073	0.260	0	1
The characteristics of firms					
Size	452	0.608	0.489	0	1
Food	452	0.243	0.430	0	1
Chemical & petroleum	452	0.177	0.382	0	1
Electrical apparatus	452	0.020	0.140	0	1
Automotive	452	0.046	0.211	0	1

TABLE B. Coverage of Sub-Modes

Mode	Coverage of Sub-Modes		Explanation
	Japan	Thailand	
Research and development (R&D)	• Joint R&D • Consignment of R&D • Funding for university research • Exchange of research sample	• Joint R&D • Contract out R&D • Co-publication	• Joint or Collaborative R&D: Both or all of parties make a substantial contribution to the resource requirements • Contract out or Commission: Research commissioned by a private firm to pursue a problem of interest • Co-publication: Both or all of parties jointly publish publication which is output of R&D activity • Fund for university research: Research paid for by an external party • Exchange of research sample: It is defined as the transfer of tangible research sample between two organizations
Consultancy	Technical guidance	Academic consultant	Consultancy is a service provided by expert staff
Infrastructure		• Use of testing service • Share of technical infrastructure	Testing service and use of infrastructure: development, analysis and testing for industrial products and processes in university department
Human resource transfer	Personnel exchange	• Temporary personnel exchange • Student internship • Training for employees	Multi-context learning mechanisms such as training of industry employees, postgraduate training in industry, graduate trainees and secondments to industry, adjunct faculty
Informal interaction		• Meeting or conference • Personnel contact	Formation of social relationships and networks at conferences, etc.
Intellectual property (IP) licensing	Technology licensing	Technology licensing	Transfer of university-generated IP (such as patents) to firms, e.g., via licensing
Business venture	Business venture		Development and commercial exploitation of technologies pursued by academic inventors through a company they (partly) own

Source: Adapted from Shartinger, et al. (2002); Perkmann and Walsh (2007); Eom and Lee (2009); Ponomariov and Boardman (2012); Vea (2013)